

**TLV5616C, TLV5616I**  
**2.7-V TO 5.5-V LOW POWER 12-BIT DIGITAL-TO-ANALOG**  
**CONVERTERS WITH POWER DOWN**

SLAS152D – DECEMBER 1997 – REVISED APRIL 2004

- 12-Bit Voltage Output DAC
- Programmable Settling Time vs Power Consumption  
3  $\mu$ s in Fast Mode  
9  $\mu$ s in Slow Mode
- Ultra Low Power Consumption:  
900  $\mu$ W Typ in Slow Mode at 3 V  
2.1 mW Typ in Fast Mode at 3 V
- Differential Nonlinearity . . . <0.5 LSB Typ
- Compatible With TMS320 and SPI Serial Ports
- Power-Down Mode (10 nA)
- Buffered High-Impedance Reference Input
- Voltage Output Range . . . 2 Times the Reference Input Voltage
- Monotonic Over Temperature
- Available in MSOP Package

#### applications

- Digital Servo Control Loops
- Digital Offset and Gain Adjustment
- Industrial Process Control
- Machine and Motion Control Devices
- Mass Storage Devices

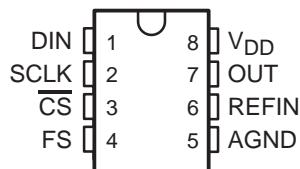
#### description

The TLV5616 is a 12-bit voltage output digital-to-analog converter (DAC) with a flexible 4-wire serial interface. The 4-wire serial interface allows glueless interface to TMS320, SPI, QSPI, and Microwire serial ports. The TLV5616 is programmed with a 16-bit serial string containing 4 control and 12 data bits. Developed for a wide range of supply voltages, the TLV5616 can operate from 2.7 V to 5.5 V.

The resistor string output voltage is buffered by a x2 gain rail-to-rail output buffer. The buffer features a Class AB output stage to improve stability and reduce settling time. The settling time of the DAC is programmable to allow the designer to optimize speed versus power dissipation. The settling time is chosen by the control bits within the 16-bit serial input string. A high-impedance buffer is integrated on the REFIN terminal to reduce the need for a low source impedance drive to the terminal.

Implemented with a CMOS process, the TLV5616 is designed for single supply operation from 2.7 V to 5.5 V. The device is available in an 8-terminal SOIC package. The TLV5616C is characterized for operation from 0°C to 70°C. The TLV5616I is characterized for operation from -40°C to 85°C.

D, DGK, OR P PACKAGE  
(TOP VIEW)



#### AVAILABLE OPTIONS

TA	PACKAGE		
	SMALL OUTLINE† (D)	MSOP (DGK)	PLASTIC DIP (P)
0°C to 70°C	TLV5616CD	TLV5616CDGK	TLV5616CP
-40°C to 85°C	TLV5616ID	TLV5616IDGK	TLV5616IP

† Available in tape and reel as the TLV5616CDR and the TLV5616IDR



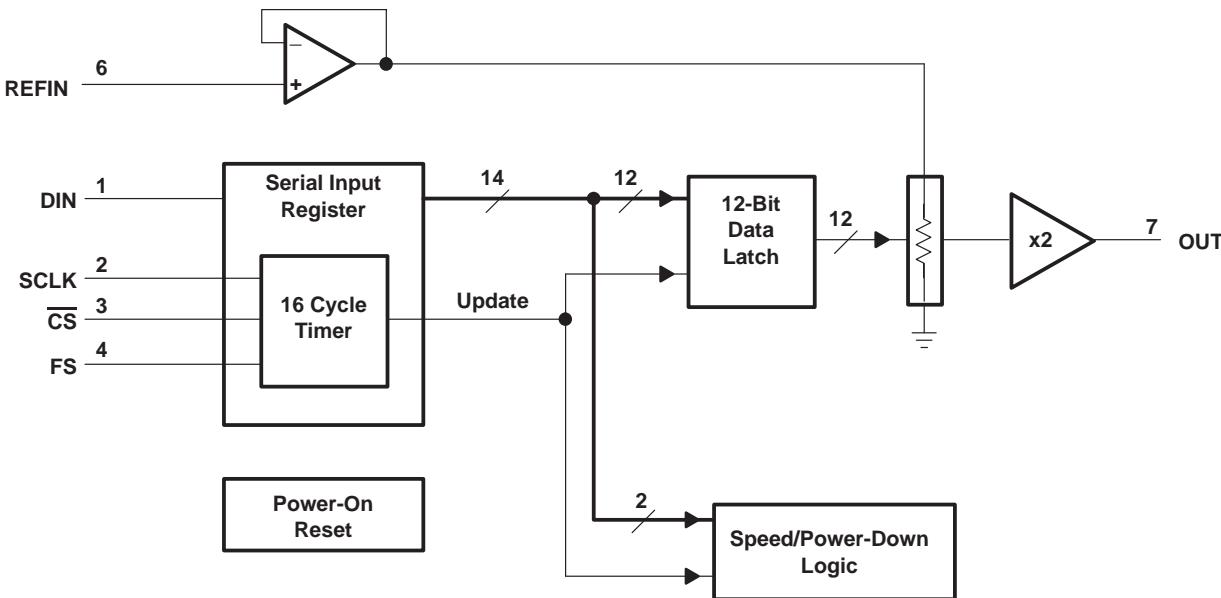
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# TLV5616C, TLV5616I

## 2.7-V TO 5.5-V LOW POWER 12-BIT DIGITAL-TO-ANALOG CONVERTERS WITH POWER DOWN

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### functional block diagram



### Terminal Functions

TERMINAL NAME NO.	I/O	DESCRIPTION
AGND	5	Analog ground
CS	I	Chip select. Digital input used to enable and disable inputs, active low.
DIN	I	Serial digital data input
FS	I	Frame sync. Digital input used for 4-wire serial interfaces such as the TMS320 DSP interface.
OUT	O	DAC analog output
REFIN	I	Reference analog input voltage
SCLK	I	Serial digital clock input
V <sub>DD</sub>	8	Positive power supply

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**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†**

Supply voltage ( $V_{DD}$ to AGND) .....	7 V
Reference input voltage range .....	–0.3 V to $V_{DD}$ + 0.3 V
Digital input voltage range .....	–0.3 V to $V_{DD}$ + 0.3 V
Operating free-air temperature range, $T_A$ : TLV5616C .....	0°C to 70°C
TLV5616I .....	–40°C to 85°C
Storage temperature range, $T_{STG}$ .....	–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	260°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

**recommended operating conditions**

		MIN	NOM	MAX	UNIT
Supply voltage, $V_{DD}$	$V_{DD} = 5$ V	4.5	5	5.5	V
	$V_{DD} = 3$ V	2.7	3	3.3	V
High-level digital input voltage, $V_{IH}$	$DV_{DD} = 2.7$ V	2			V
	$DV_{DD} = 5.5$ V	2.4			V
Low-level digital input voltage, $V_{IL}$	$DV_{DD} = 2.7$ V		0.6		V
	$DV_{DD} = 5.5$ V		1		V
Reference voltage, $V_{ref}$ to REFIN terminal	$V_{DD} = 5$ V (see Note 1)	AGND	2.048	$V_{DD} - 1.5$	V
Reference voltage, $V_{ref}$ to REFIN terminal	$V_{DD} = 3$ V (see Note 1)	AGND	1.024	$V_{DD} - 1.5$	V
Load resistance, $R_L$		2	10		kΩ
Load capacitance, $C_L$			100		pF
Clock frequency, $f_{CLK}$			20		MHz
Operating free-air temperature, $T_A$	TLV5616C	0	70		°C
	TLV5616I	–40	85		°C

NOTE 1: Due to the x2 output buffer, a reference input voltage  $\geq V_{DD}/2$  causes clipping of the transfer function.

**electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)**

**power supply**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$I_{DD}$	Power supply current	$V_{DD} = 5$ V, $V_{ref} = 2.048$ V, No load, All inputs = AGND or $V_{DD}$ , DAC latch = 0x800	Fast	0.9	1.35		mA
			Slow	0.4	0.6		mA
		$V_{DD} = 3$ V, $V_{ref} = 1.024$ V No load, All inputs = AGND or $V_{DD}$ , DAC latch = 0x800	Fast	0.7	1.1		mA
			Slow	0.3	0.45		mA
Power down supply current (see Figure 12)				10			nA
PSRR	Power supply rejection ratio	Zero scale	See Note 2		–80		dB
		Full scale	See Note 3		–80		
Power on threshold voltage, POR				2			V

NOTES: 2. Power supply rejection ratio at zero scale is measured by varying  $V_{DD}$  and is given by:

$$PSRR = 20 \log [(E_{ZS}(V_{DDmax}) - E_{ZS}(V_{DDmin}))/V_{DDmax}]$$

3. Power supply rejection ratio at full scale is measured by varying  $V_{DD}$  and is given by:

$$PSRR = 20 \log [(E_G(V_{DDmax}) - E_G(V_{DDmin}))/V_{DDmax}]$$

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**electrical characteristics over recommended operating free-air temperature range (unless otherwise noted) (continued)****static DAC specifications  $R_L = 10 \text{ k}\Omega$ ,  $C_L = 100 \text{ pF}$** 

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Resolution		12	12		bits
INL Integral nonlinearity	See Note 4		$\pm 1.9$	$\pm 4$	LSB
DNL Differential nonlinearity	See Note 5		$\pm 0.5$	$\pm 1$	LSB
$E_{ZS}$ Zero-scale error (offset error at zero scale)	See Note 6			$\pm 10$	mV
Zero-scale-error temperature coefficient	See Note 7		10		ppm/ $^{\circ}\text{C}$
$E_G$ Gain error	See Note 8			$\pm 0.6$	% of FS voltage
Gain-error temperature coefficient	See Note 9	10			ppm/ $^{\circ}\text{C}$

NOTES: 4. The relative accuracy or integral nonlinearity (INL) sometimes referred to as linearity error, is the maximum deviation of the output from the line between zero and full scale excluding the effects of zero code and full-scale errors. Tested from code 10 to code 4095.  
 5. The differential nonlinearity (DNL) sometimes referred to as differential error, is the difference between the measured and ideal 1 LSB amplitude change of any two adjacent codes. Monotonic means the output voltage changes in the same direction (or remains constant) as a change in the digital input code. Tested from code 10 to code 4095.  
 6. Zero-scale error is the deviation from zero voltage output when the digital input code is zero.  
 7. Zero-scale-error temperature coefficient is given by:  $E_{ZS} \text{ TC} = [E_{ZS} (T_{\text{max}}) - E_{ZS} (T_{\text{min}})]/V_{\text{ref}} \times 10^6/(T_{\text{max}} - T_{\text{min}})$ .  
 8. Gain error is the deviation from the ideal output ( $2V_{\text{ref}} - 1$  LSB) with an output load of  $10 \text{ k}\Omega$  excluding the effects of the zero-error.  
 9. Gain temperature coefficient is given by:  $E_G \text{ TC} = [E_G (T_{\text{max}}) - E_G (T_{\text{min}})]/V_{\text{ref}} \times 10^6/(T_{\text{max}} - T_{\text{min}})$ .

**output specifications**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_O$ Voltage output range	$R_L = 10 \text{ k}\Omega$	0	$V_{\text{DD}} - 0.1$		V
Output load regulation accuracy	$R_L = 2 \text{ k}\Omega$ , vs $10 \text{ k}\Omega$		0.1	$\pm 0.25$	% of FS voltage

**reference input (REF)**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_I$ Input voltage range		0	$V_{\text{DD}} - 1.5$		V
$R_I$ Input resistance			10		$\text{M}\Omega$
$C_I$ Input capacitance			5		pF
Reference input bandwidth	$\text{REFIN} = 0.2 \text{ V}_{\text{pp}} + 1.024 \text{ V dc}$	Slow	525		kHz
		Fast	1.3		MHz
Reference feed through	$\text{REFIN} = 1 \text{ V}_{\text{pp}}$ at $1 \text{ kHz} + 1.024 \text{ V dc}$ (see Note 10)		-75		dB

NOTE 10: Reference feedthrough is measured at the DAC output with an input code = 0x000.

**digital inputs**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{IH}$ High-level digital input current	$V_I = V_{\text{DD}}$			$\pm 1$	$\mu\text{A}$
$I_{IL}$ Low-level digital input current	$V_I = 0 \text{ V}$			$\pm 1$	$\mu\text{A}$
$C_I$ Input capacitance			3		pF

**operating characteristics over recommended operating free-air temperature range (unless otherwise noted)**

**analog output dynamic performance**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
ts(FS)	Output settling time, full scale	$R_L = 10 \text{ k}\Omega$ , See Note 11	$C_L = 100 \text{ pF}$ , Fast	3	5.5		$\mu\text{s}$
				9	20		
ts(CC)	Output settling time, code to code	$R_L = 10 \text{ k}\Omega$ , See Note 12	$C_L = 100 \text{ pF}$ , Slow	1			$\mu\text{s}$
				2			$\mu\text{s}$
SR	Slew rate	$R_L = 10 \text{ k}\Omega$ , See Note 13	$C_L = 100 \text{ pF}$ , Fast	3.6			$\text{V}/\mu\text{s}$
				0.9			
Glitch energy		Code transition from 0x7FF to 0x800		10			$\text{nV}\cdot\text{s}$
S/N	Signal to noise	$f_s = 400 \text{ KSPS}$ $f_{out} = 1.1 \text{ kHz}$ , $R_L = 10 \text{ k}\Omega$ , $C_L = 100 \text{ pF}$ , $BW = 20 \text{ kHz}$		74			$\text{dB}$
S/(N+D)	Signal to noise + distortion			66			$\text{dB}$
THD	Total harmonic distortion			-68			$\text{dB}$
Spurious free dynamic range				70			$\text{dB}$

NOTES: 11. Settling time is the time for the output signal to remain within  $\pm 0.5$  LSB of the final measured value for a digital input code change of 0x080 to 0x3FF or 0x3FF to 0x080. Not tested, ensured by design.  
 12. Settling time is the time for the output signal to remain within  $\pm 0.5$  LSB of the final measured value for a digital input code change of one count. Code change from 0x1FF to 0x200. Not tested, ensured by design.  
 13. Slew rate determines the time it takes for a change of the DAC output from 10% to 90% full-scale voltage.

**digital input timing requirements**

		MIN	NOM	MAX	UNIT
tsu(CS-FS)	Setup time, $\overline{CS}$ low before FS $\downarrow$	10			ns
tsu(FS-CK)	Setup time, FS low before first negative SCLK edge	8			ns
tsu(C16-FS)	Setup time, sixteenth negative edge after FS low on which bit D0 is sampled before rising edge of FS	10			ns
tsu(C16-CS)	Setup time, sixteenth positive SCLK edge (first positive after D0 is sampled) before $\overline{CS}$ rising edge. If FS is used instead of the sixteenth positive edge to update the DAC, then the setup time is between the FS rising edge and $\overline{CS}$ rising edge.	10			ns
$t_{wH}$	Pulse duration, SCLK high	25			ns
$t_{wL}$	Pulse duration, SCLK low	25			ns
tsu(D)	Setup time, data ready before SCLK falling edge	8			ns
$t_h(D)$	Hold time, data held valid after SCLK falling edge	5			ns
$t_{wH}(FS)$	Pulse duration, FS high	20			ns

## PARAMETER MEASUREMENT INFORMATION

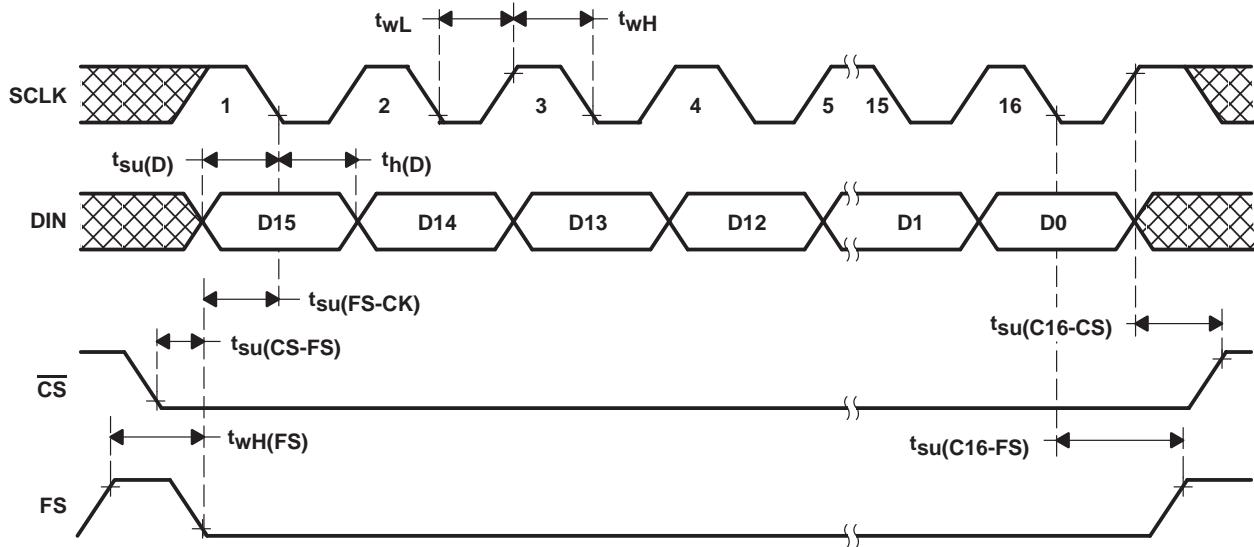
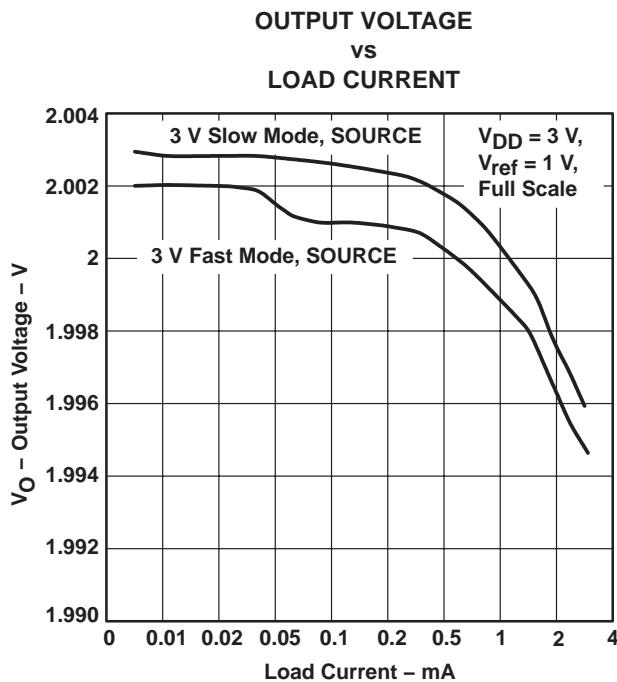
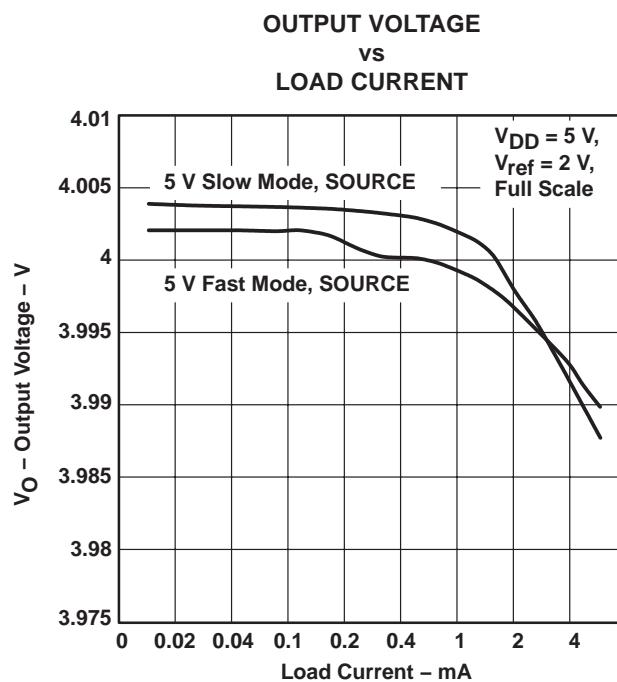


Figure 1. Timing Diagram

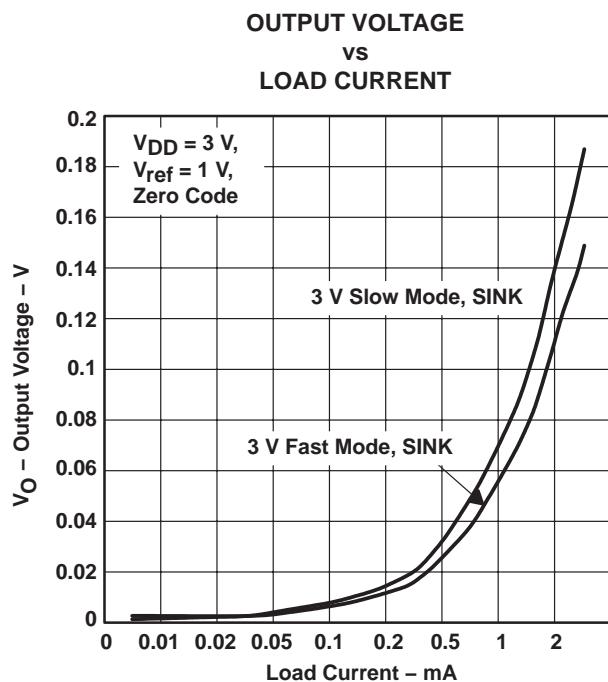
### TYPICAL CHARACTERISTICS



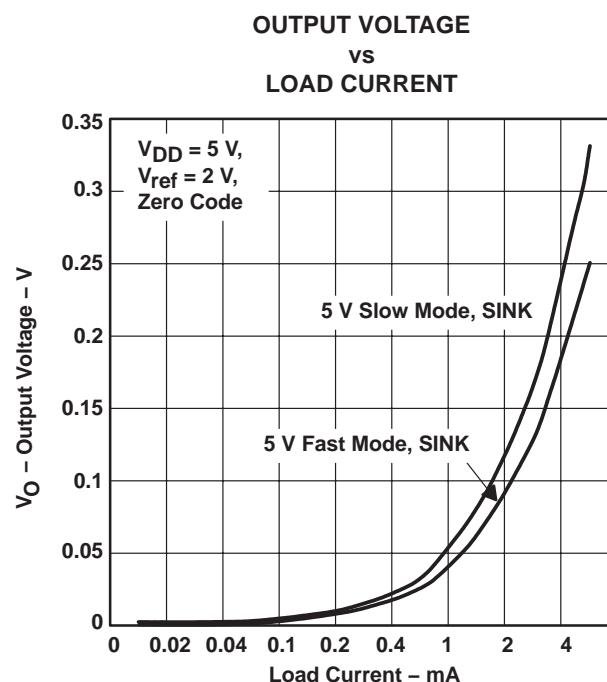
**Figure 2**



**Figure 3**

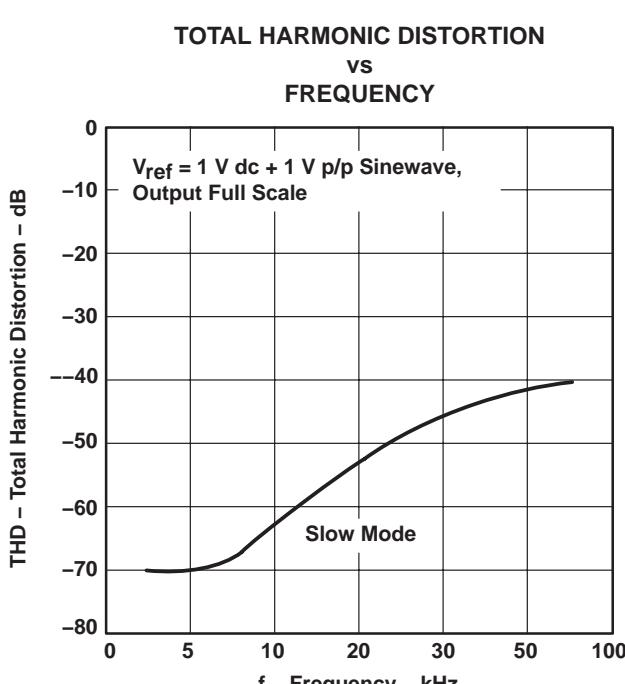
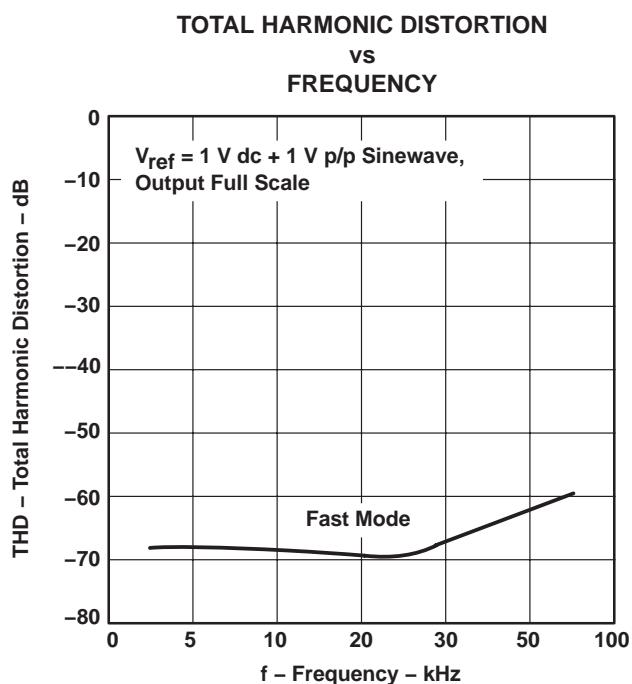
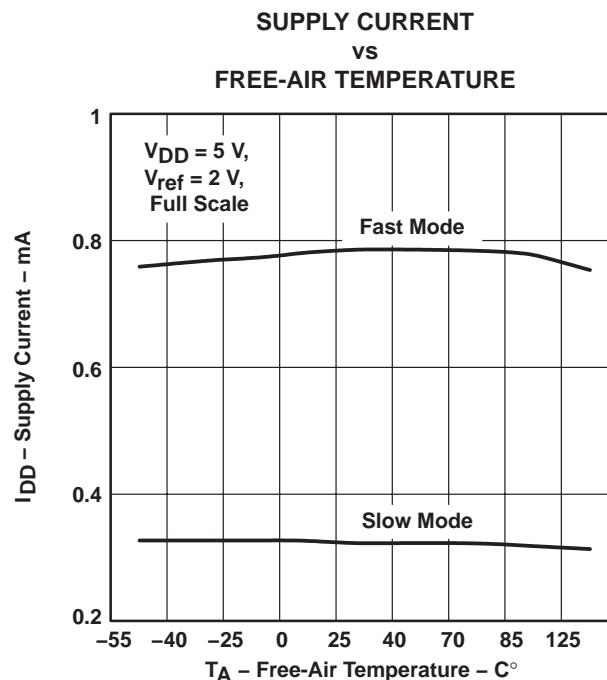
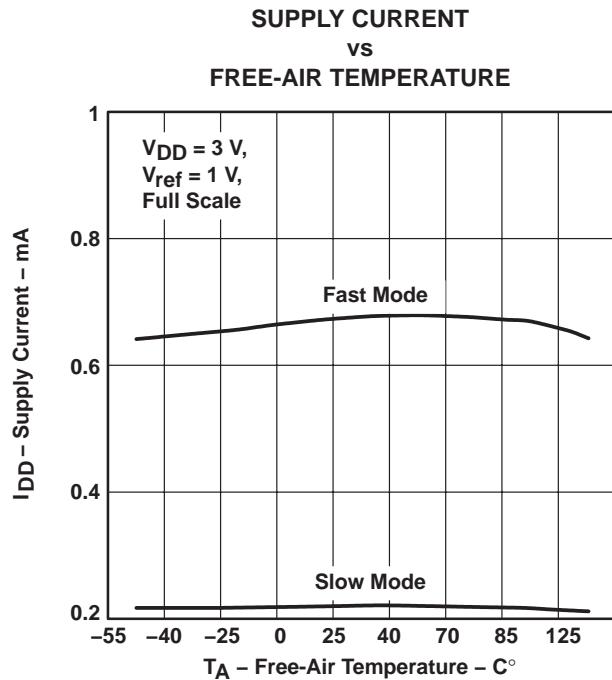


**Figure 4**



**Figure 5**

## TYPICAL CHARACTERISTICS



**TYPICAL CHARACTERISTICS**

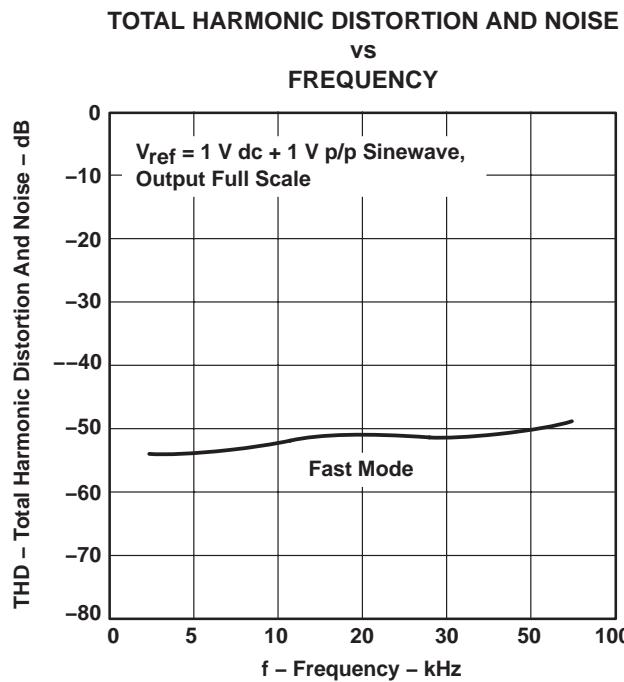


Figure 10

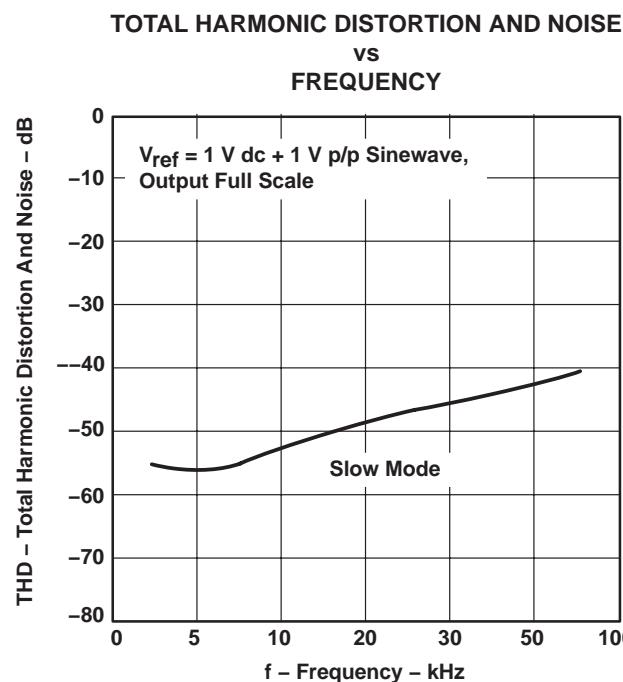


Figure 11

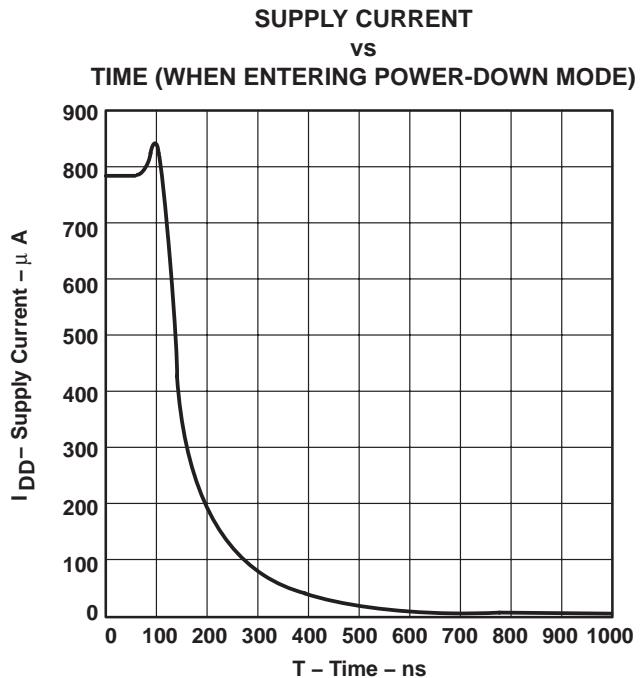


Figure 12

## TYPICAL CHARACTERISTICS

## INTEGRAL NONLINEARITY ERROR

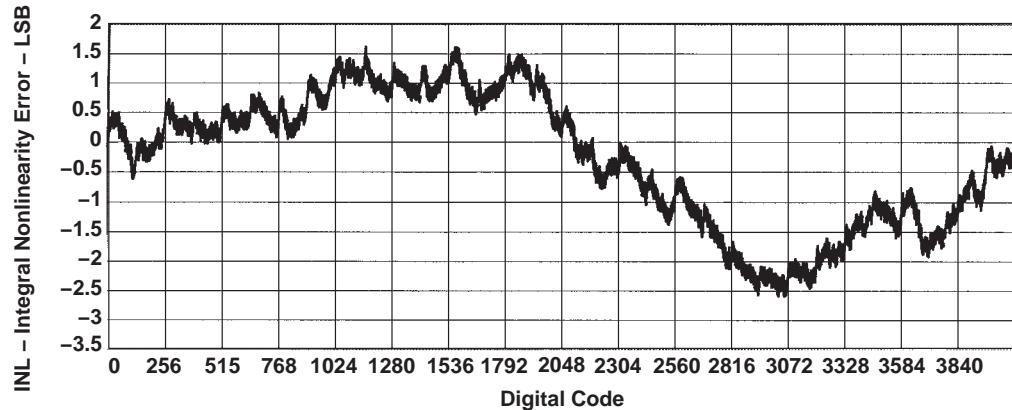


Figure 13

## DIFFERENTIAL NONLINEARITY ERROR

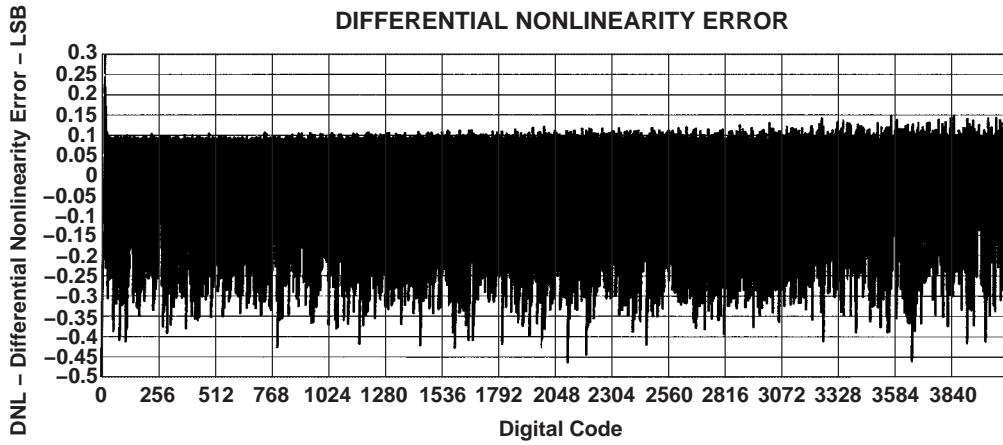


Figure 14

## APPLICATION INFORMATION

### general function

The TLV5616 is a 12-bit single supply DAC based on a resistor string architecture. The device consists of a serial interface, speed and power-down control logic, a reference input buffer, a resistor string, and a rail-to-rail output buffer.

The output voltage (full scale determined by external reference) is given by:

$$2 \text{ REF} \frac{\text{CODE}}{2^n} [\text{V}]$$

where REF is the reference voltage and CODE is the digital input value within the range of  $0_{10}$  to  $2^{n-1}$ , where  $n = 12$  (bits). The 16-bit data word, consisting of control bits and the new DAC value, is illustrated in the *data format* section. A power-on reset initially resets the internal latches to a defined state (all bits zero).

### serial interface

Explanation of data transfer: First, the device has to be enabled with  $\overline{\text{CS}}$  set to low. Then, a falling edge of FS starts shifting the data bit-per-bit (starting with the MSB) to the internal register on the falling edges of SCLK. After 16 bits have been transferred or FS rises, the content of the shift register is moved to the DAC latch which updates the voltage output to the new level.

The serial interface of the TLV5616 can be used in two basic modes:

- Four wire (with chip select)
- Three wire (without chip select)

Using chip select (four wire mode), it is possible to have more than one device connected to the serial port of the data source (DSP or microcontroller). The interface is compatible with the TMS320 family. Figure 15 shows an example with two TLV5616s connected directly to a TMS320 DSP.

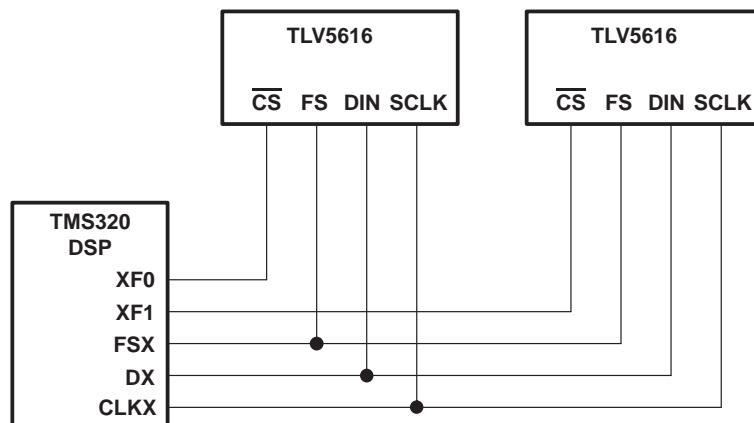


Figure 15. TMS320 Interface

## APPLICATION INFORMATION

## serial interface (continued)

If there is no need to have more than one device on the serial bus, then CS can be tied low. Figure 16 shows an example of how to connect the TLV5616 to a TMS320, SPI, or Microwire port using only three pins.

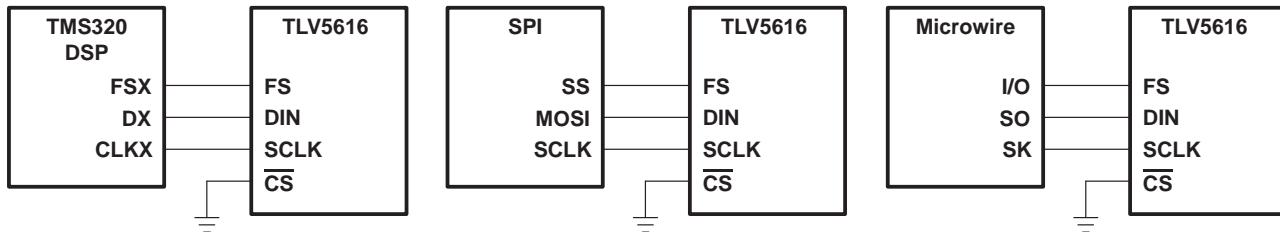


Figure 16. Three-Wire Interface

Notes on SPI and Microwire: Before the controller starts the data transfer, the software has to generate a falling edge on the I/O pin connected to FS. If the word width is 8 bits (SPI and Microwire), two write operations must be performed to program the TLV5616. After the write operation(s), the DAC output is updated automatically on the next positive clock edge following the sixteenth falling clock edge.

## serial clock frequency and update rate

The maximum serial clock frequency is given by:

$$f_{SCLKmax} = \frac{1}{t_{wH(min)} + t_{wL(min)}} = 20 \text{ MHz}$$

The maximum update rate is:

$$f_{UPDATEmax} = \frac{1}{16(t_{wH(min)} + t_{wL(min)})} = 1.25 \text{ MHz}$$

The maximum update rate is a theoretical value for the serial interface, since the settling time of the TLV5616 has to be considered also.

## data format

The 16-bit data word for the TLV5616 consists of two parts:

- Control bits (D15 . . . D12)
- New DAC value (D11 . . . D0)

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
X	SPD	PWR	X	New DAC value (12 bits)											

X: don't care

SPD: Speed control bit. 1 → fast mode 0 → slow mode

PWR: Power control bit. 1 → power down 0 → normal operation

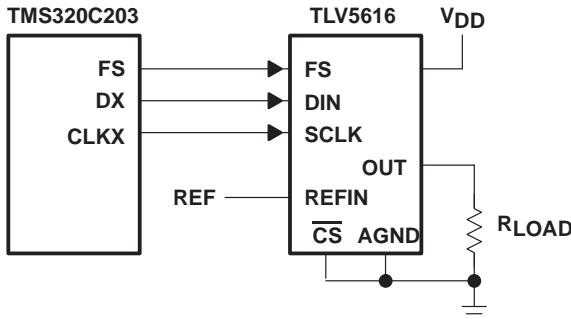
In power-down mode, all amplifiers within the TLV5616 are disabled.

## APPLICATION INFORMATION

### TLV5616 interfaced to TMS320C203 DSP

#### hardware interfacing

Figure 17 shows an example how to connect the TLV5616 to a TMS320C203 DSP. The serial interface of the TLV5616 is ideally suited to this configuration, using a maximum of four wires to make the necessary connections. In applications where only one synchronous serial peripheral is used, the interface can be simplified even further by pulling  $\overline{CS}$  low all the time as shown in the figure.



**Figure 17. TLV5616 to DSP Interface**

#### software

No setup procedure is needed to access the TLV5616. The output voltage can be set using just a single command.

```
out    data_addr, SDTR
```

where `data_addr` points to an address location holding the control bits and the 12 data bits providing the output voltage data. `SDTR` is the address of the transmit FIFO of the synchronous serial port.

The following code shows how to use the timer of the TMS320C203 as a time base to generate a voltage ramp with the TLV5616.

A timer interrupt is generated every 205  $\mu$ s. The corresponding interrupt service routine increments the output code (stored at 0x0064) for the DAC, adds the DAC control bits to the four most significant bits, and writes the new code to the TLV5616. The resulting period of the saw waveform is:

$$\pi = 4096 \times 205 \text{ E-6 s} = 0.84 \text{ s}$$

```
;*****
;* Title   : Ramp generation with TLV5616
;* Version : 1.0
;* DSP     : TI TMS320C203
;* © (1998) Texas Instruments Incorporated
;*****  

;----- I/O and memory mapped regs -----
.include "regs.asm"
;----- vectors -----
.ps    0h
b     start
b     INT1
b     INT23
b     TIM_ISR
```

## APPLICATION INFORMATION

```

;*****
;* Main Program
;*****
.ps      1000h
.entry

start:
; disable interrupts
    setc    INTM      ; disable maskable interrupts
    splk    #0ffffh, IFR
    splk    #0004h, IMR

; set up the timer to interrupt every 205us
    splk    #0000h, 60h
    splk    #00FFh, 61h
    out     61h, PRD
    out     60h, TIM
    splk    #0c2fh, 62h
    out     62h, TCR

; Configure SSP to use internal clock, internal frame sync and burst mode
    splk    #0CC0Eh, 63h
    out     63h, SSPCR
    splk    #0CC3Eh, 63h
    out     63h, SSPCR

    splk    #0000h, 64h ; set initial DAC value

; enable interrupts
    clrc    INTM      ; enable maskable interrupts

; loop forever!
next:   idle           ;wait for interrupt
        b     next

; all else fails stop here
done:   b     done      ;hang there

;*****
;* Interrupt Service Routines
;*****
INT1:   ret      ;do nothing and return
INT23:  ret      ;do nothing and return

TIM_ISR:
    lacl    64h      ; restore counter value to ACC
    add     #1h      ; increment DAC value
    and     #0FFFh    ; mask 4 MSBs
    sacl    64h      ; store 12 bit counter value
    or      #4000h    ; set DAC control bits
    sacl    65h      ; store DAC value
    out     65h, SDTR ; send data

    clrc    intm      ; re-enable interrupts
    ret

.END

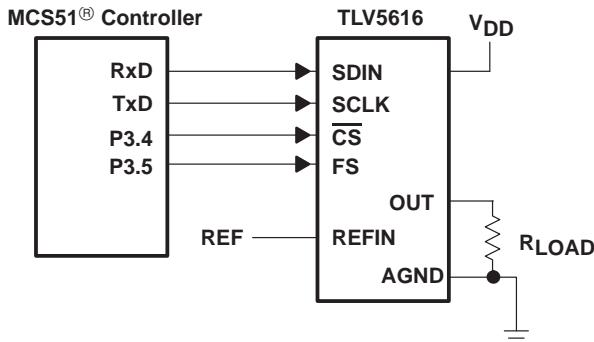
```

## APPLICATION INFORMATION

### TLV5616 interfaced to MCS51® microcontroller

#### hardware interfacing

Figure 18 shows an example of how to connect the TLV5616 to an MCS51® compatible microcontroller. The serial DAC input data and external control signals are sent via I/O port 3 of the controller. The serial data is sent on the RxD line, with the serial clock output on the TxD line. P3.4 and P3.5 are configured as outputs to provide the chip select and frame sync signals for the TLV5616.



**Figure 18. TLV5616 to MCS51® Controller Interface**

#### software

The example program puts out a sine wave on the OUT pin.

The on-chip timer is used to generate interrupts at a fixed frequency. The related interrupt service routine fetches and writes the next sample to the DAC. The samples are stored in a lookup table, which describes one full period of a sine wave.

The serial port of the controller is used in mode 0, which transmits 8 bits of data on RxD, accompanied by a synchronous clock on TxD. Two writes concatenated together are required to write a complete word to the TLV5616. The CS and FS signals are provided in the required fashion through control of I/O port 3, which has bit addressable outputs.

```

;*****
;* Title   : Ramp generation with TLV5616
;* Version : 1.0
;* MCU    : INTEL MCS51®
;* © (1998) Texas Instruments Incorporated
;*****



;-----
; Program function declaration
;-----



NAME    GENSINE

MAIN    SEGMENT      CODE
ISR     SEGMENT      CODE
SINTBL SEGMENT      CODE
VAR1   SEGMENT      DATA
STACK  SEGMENT      IDATA

;-----
; Code start at address 0, jump to start
;-----



CSEG AT 0

```

MCS is a registered trademark of Intel Corporation

## APPLICATION INFORMATION

```

LJMP      start      ; Execution starts at address 0 on power-up.

;-----  

; Code in the timer0 interrupt vector  

;-----  

CSEG AT 0BH

LJMP      timer0isr ; Jump vector for timer 0 interrupt is 000Bh
;-----  

; Define program variables
;-----  

RSEG      VAR1

rolling_ptr: DS 1
;-----  

; Interrupt service routine for timer 0 interrupts
;-----  

RSEG      ISR

timer0isr:
PUSH      PSW
PUSH      ACC

CLR      T0          ; set CSB low
CLR      T1          ; set FS low

; The signal to be output on the dac is a sine function. One cycle of a sine wave is
; held in a table @ sinevals as 32 samples of msb, lsb pairs (64 bytes). The pointer,
; rolling_ptr, rolls round the table of samples incrementing by 2 bytes (1 sample) on
; each interrupt (at the end of this routine).

MOV      DPTR,#sinevals ; set DPTR to the start of the table of sine signal values
MOV      A,rolling_ptr ; ACC loaded with the pointer into the sine table

MOVC     A,@A+DPTR      ; get msb from the table
ORL      A, #00H         ; set control bits
MOV      SBUF,A          ; send out msb of data word

MOVA,rolling_ptr ; move rolling pointer in to ACC
INC      A          ; increment ACC holding the rolling pointer
MOVC     A,@A+DPTR      ; which is the lsb of this sample, now in ACC

MSB_TX:
JNB      TI, MSB_TX      ; wait for transmit to complete
CLR      TI          ; clear for new transmit
MOV      SBUF,A          ; and send out the lsb

LSB_TX:
JNB      TI, LSB_TX      ; wait for lsb transmit to complete
SETB     T1          ; set FS = 1
CLR      TI          ; clear for new transmit

MOV      A,rolling_ptr      ; load ACC with rolling pointer
INC      A          ; increment the ACC twice, to get next sample
INC      A
ANL      A,#03FH        ; wrap back round to 0 if >64
MOV      rolling_ptr,A    ; move value held in ACC back to the rolling pointer

SETB     T0          ; CSB high

POP      ACC
POP      PSW

RETI
;-----  

; Set up stack
;-----  


```

## APPLICATION INFORMATION

```

RSEG  STACK
DS    10h           ; 16 Byte Stack!

;-----;
; Main Program
;-----;

RSEG  MAIN

start:
    MOV    SP,#STACK-1 ; first set Stack Pointer
    CLR    A
    MOV    SCON,A      ; set serial port 0 to mode 0
    MOV    TMOD,#02H   ; set timer 0 to mode 2 - auto-reload
    MOV    TH0,#0C8H   ; set TH0 for 16.67 kHs interrupts
    SETB   T1          ; set FS = 1
    SETB   T0          ; set CSB = 1
    SETB   ET0          ; enable timer 0 interrupts
    SETB   EA           ; enable all interrupts
    MOV    rolling_ptr,A ; set rolling pointer to 0
    SETB   TR0          ; start timer 0

always:
    SJMP   always      ; while(1) !
    RET

;-----;
; Table of 32 sine wave samples used as DAC data
;-----;

RSEG  SINTBL
sinevals:
    DW    01000H
    DW    0903EH
    DW    05097H
    DW    0305CH
    DW    0B086H
    DW    070CAH
    DW    0F0E0H
    DW    0F06EH
    DW    0F039H
    DW    0F06EH
    DW    0F0E0H
    DW    070CAH
    DW    0B086H
    DW    0305CH
    DW    05097H
    DW    0903EH
    DW    01000H
    DW    06021H
    DW    0A0E8H
    DW    0C063H
    DW    040F9H
    DW    080B5H
    DW    0009FH
    DW    00051H
    DW    00026H
    DW    00051H
    DW    0009FH
    DW    080B5H
    DW    040F9H
    DW    0C063H
    DW    0A0E8H
    DW    06021H

END

```

## APPLICATION INFORMATION

## linearity, offset, and gain error using single ended supplies

When an amplifier is operated from a single supply, the voltage offset can still be either positive or negative. With a positive offset, the output voltage changes on the first code change. With a negative offset, the output voltage may not change with the first code, depending on the magnitude of the offset voltage.

The output amplifier attempts to drive the output to a negative voltage. However, because the most negative supply rail is ground, the output cannot drive below ground and clamps the output at 0 V.

The output voltage then remains at zero until the input code value produces a sufficient positive output voltage to overcome the negative offset voltage, resulting in the transfer function shown in Figure 19.

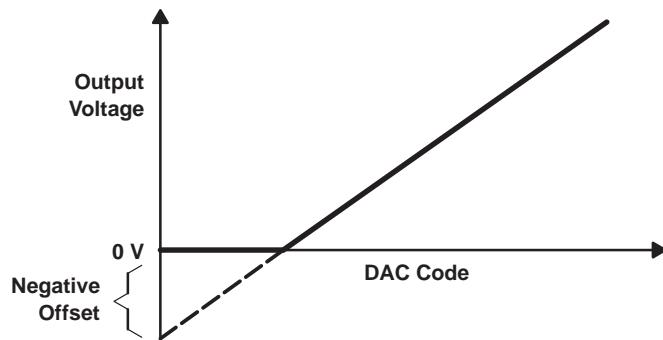


Figure 19. Effect of Negative Offset (Single Supply)

This offset error, not the linearity error, produces this breakpoint. The transfer function would have followed the dotted line if the output buffer could drive below the ground rail.

For a DAC, linearity is measured between zero-input code (all inputs 0) and full-scale code (all inputs 1) after offset and full scale are adjusted out or accounted for in some way. However, single supply operation does not allow for adjustment when the offset is negative due to the breakpoint in the transfer function. So the linearity is measured between full-scale code and the lowest code that produces a positive output voltage.

## power-supply bypassing and ground management

Printed-circuit boards that use separate analog and digital ground planes offer the best system performance. Wire-wrap boards do not perform well and should not be used. The two ground planes should be connected together at the low-impedance power-supply source. The best ground connection may be achieved by connecting the DAC AGND terminal to the system analog ground plane, making sure that analog ground currents are well managed and there are negligible voltage drops across the ground plane.

A 0.1- $\mu$ F ceramic-capacitor bypass should be connected between  $V_{DD}$  and AGND and mounted with short leads as close as possible to the device. Use of ferrite beads may further isolate the system analog supply from the digital power supply.

Figure 20 shows the ground plane layout and bypassing technique.

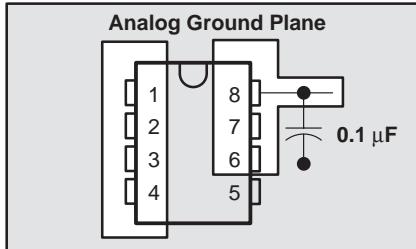


Figure 20. Power-Supply Bypassing

## APPLICATION INFORMATION

### definitions of specifications and terminology

#### integral nonlinearity (INL)

The relative accuracy or integral nonlinearity (INL), sometimes referred to as linearity error, is the maximum deviation of the output from the line between zero and full scale excluding the effects of zero code and full-scale errors.

#### differential nonlinearity (DNL)

The differential nonlinearity (DNL), sometimes referred to as differential error, is the difference between the measured and ideal 1 LSB amplitude change of any two adjacent codes. Monotonic means the output voltage changes in the same direction (or remains constant) as a change in the digital input code.

#### zero-scale error ( $E_{zs}$ )

Zero-scale error is defined as the deviation of the output from 0 V at a digital input value of 0.

#### gain error ( $E_g$ )

Gain error is the error in slope of the DAC transfer function.

#### signal-to-noise ratio + distortion (S/N+D)

S/N+D is the ratio of the rms value of the output signal to the rms sum of all other spectral components below the Nyquist frequency, including harmonics but excluding dc. The value for S/N+D is expressed in decibels.

#### spurious free dynamic range (SFDR)

SFDR is the difference between the rms value of the output signal and the rms value of the largest spurious signal within a specified bandwidth. The value for SFDR is expressed in decibels.

#### total harmonic distortion (THD)

THD is the ratio of the rms sum of the first six harmonic components to the rms value of the fundamental signal and is expressed in decibels.

**PACKAGING INFORMATION**

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
<a href="#">TLV5616CD</a>	Active	Production	SOIC (D)   8	75   TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	5616C
TLV5616CD.A	Active	Production	SOIC (D)   8	75   TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	5616C
<a href="#">TLV5616CDGK</a>	Active	Production	VSSOP (DGK)   8	80   TUBE	Yes	NIPDAUAG	Level-1-260C-UNLIM	0 to 70	ABF
TLV5616CDGK.A	Active	Production	VSSOP (DGK)   8	80   TUBE	Yes	NIPDAUAG	Level-1-260C-UNLIM	0 to 70	ABF
<a href="#">TLV5616CDR</a>	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	5616C
TLV5616CDR.A	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	5616C
<a href="#">TLV5616CP</a>	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU	N/A for Pkg Type	0 to 70	TLV5616CP
TLV5616CP.A	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU	N/A for Pkg Type	0 to 70	TLV5616CP
<a href="#">TLV5616ID</a>	Active	Production	SOIC (D)   8	75   TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	5616I
TLV5616ID.A	Active	Production	SOIC (D)   8	75   TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	5616I
<a href="#">TLV5616IDGK</a>	Active	Production	VSSOP (DGK)   8	80   TUBE	Yes	NIPDAUAG	Level-1-260C-UNLIM	-40 to 85	AJE
TLV5616IDGK.A	Active	Production	VSSOP (DGK)   8	80   TUBE	Yes	NIPDAUAG	Level-1-260C-UNLIM	-40 to 85	AJE
<a href="#">TLV5616IDGKR</a>	Active	Production	VSSOP (DGK)   8	2500   LARGE T&R	Yes	NIPDAUAG	Level-1-260C-UNLIM	-40 to 85	AJE
TLV5616IDGKR.A	Active	Production	VSSOP (DGK)   8	2500   LARGE T&R	Yes	NIPDAUAG	Level-1-260C-UNLIM	-40 to 85	AJE
<a href="#">TLV5616IDR</a>	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	5616I
TLV5616IDR.A	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	5616I
<a href="#">TLV5616IP</a>	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 85	TLV5616IP
TLV5616IP.A	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 85	TLV5616IP

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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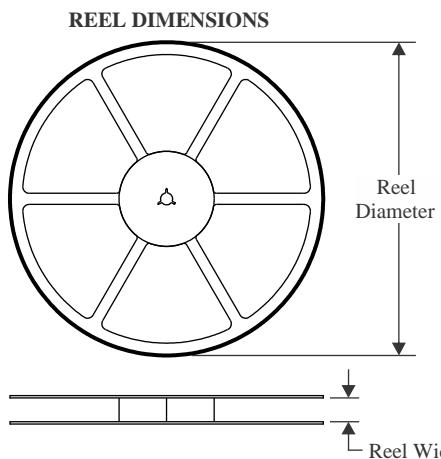
<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

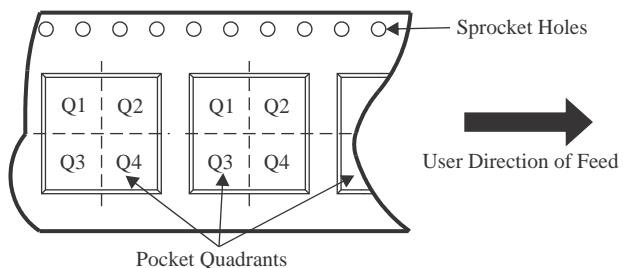
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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**TAPE AND REEL INFORMATION**


A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLV5616CDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TLV5616IDGKR	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
TLV5616IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV5616CDR	SOIC	D	8	2500	350.0	350.0	43.0
TLV5616IDGKR	VSSOP	DGK	8	2500	350.0	350.0	43.0
TLV5616IDR	SOIC	D	8	2500	350.0	350.0	43.0

**TUBE**


\*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (μm)	B (mm)
TLV5616CD	D	SOIC	8	75	505.46	6.76	3810	4
TLV5616CD.A	D	SOIC	8	75	505.46	6.76	3810	4
TLV5616CDGK	DGK	VSSOP	8	80	331.47	6.55	3000	2.88
TLV5616CDGK.A	DGK	VSSOP	8	80	331.47	6.55	3000	2.88
TLV5616CP	P	PDIP	8	50	506	13.97	11230	4.32
TLV5616CP.A	P	PDIP	8	50	506	13.97	11230	4.32
TLV5616ID	D	SOIC	8	75	505.46	6.76	3810	4
TLV5616ID.A	D	SOIC	8	75	505.46	6.76	3810	4
TLV5616IDGK	DGK	VSSOP	8	80	331.47	6.55	3000	2.88
TLV5616IDGK.A	DGK	VSSOP	8	80	331.47	6.55	3000	2.88
TLV5616IP	P	PDIP	8	50	506	13.97	11230	4.32
TLV5616IP.A	P	PDIP	8	50	506	13.97	11230	4.32

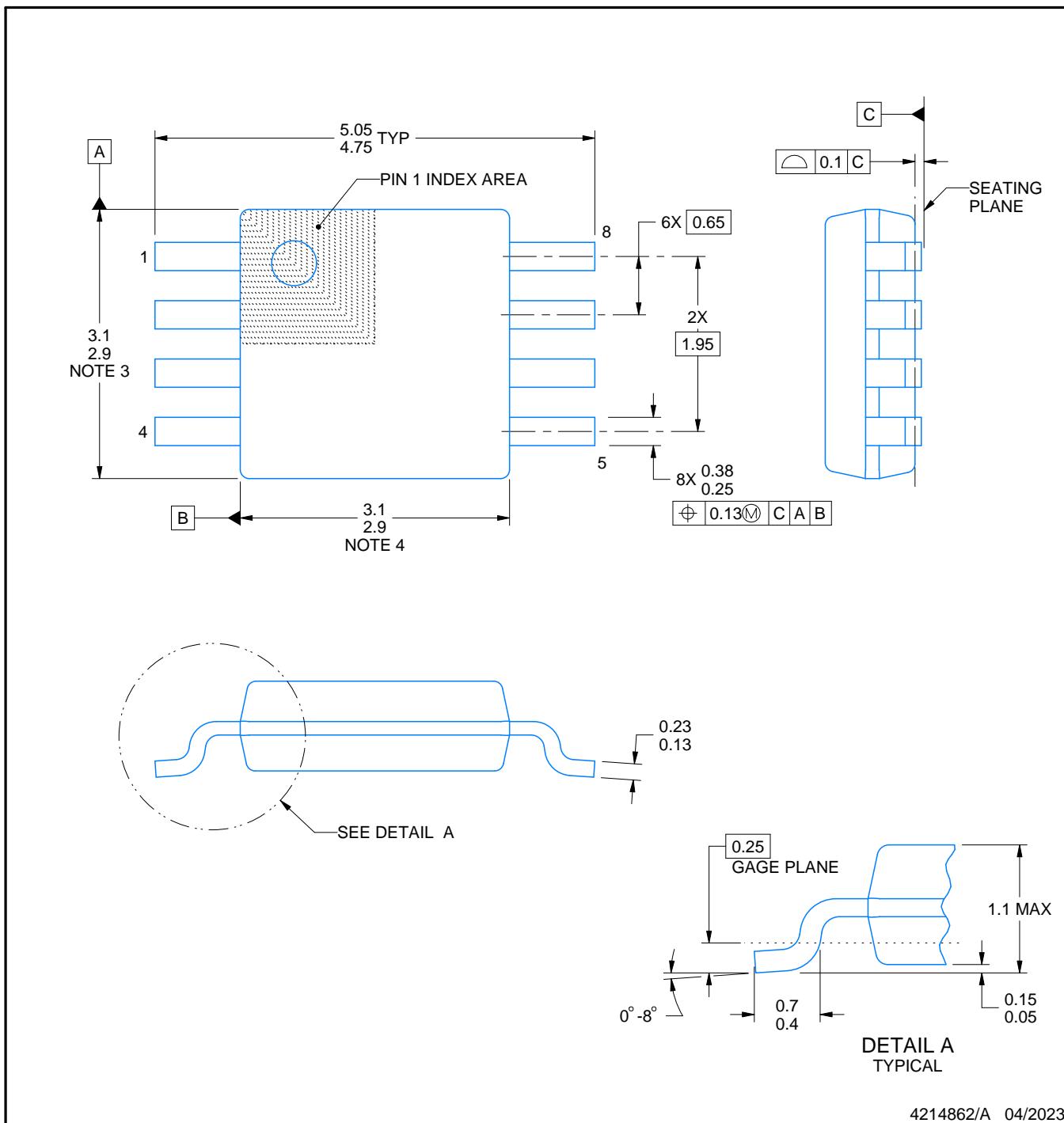
# PACKAGE OUTLINE

DGK0008A



VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



NOTES:

PowerPAD is a trademark of Texas Instruments.

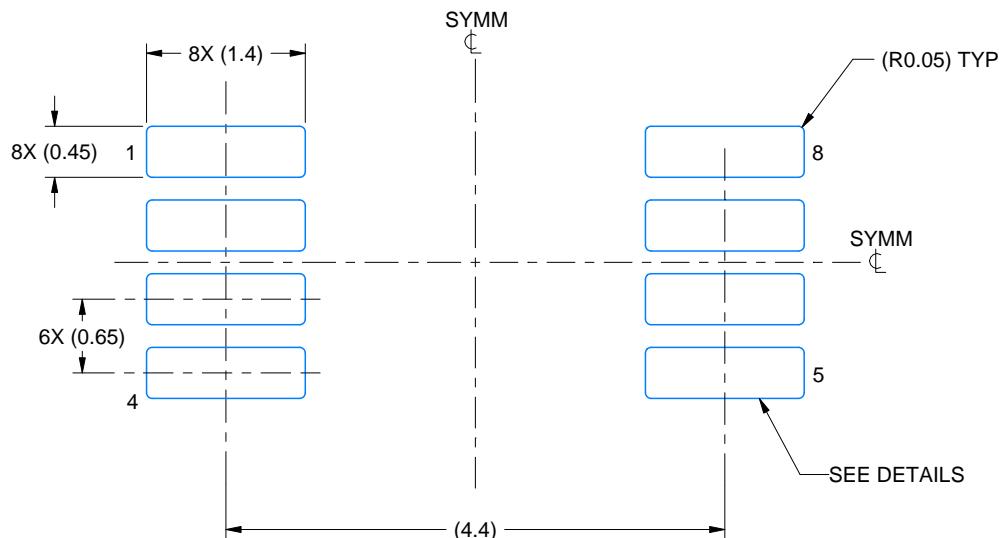
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-187.

# EXAMPLE BOARD LAYOUT

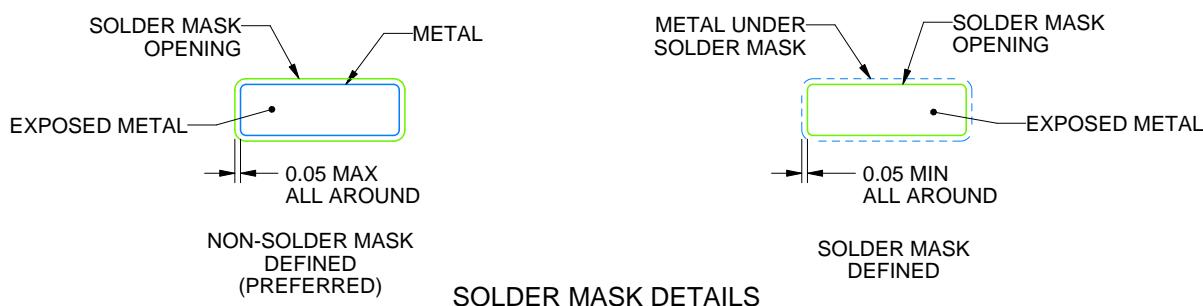
DGK0008A

™ VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 15X



SOLDER MASK DETAILS

4214862/A 04/2023

NOTES: (continued)

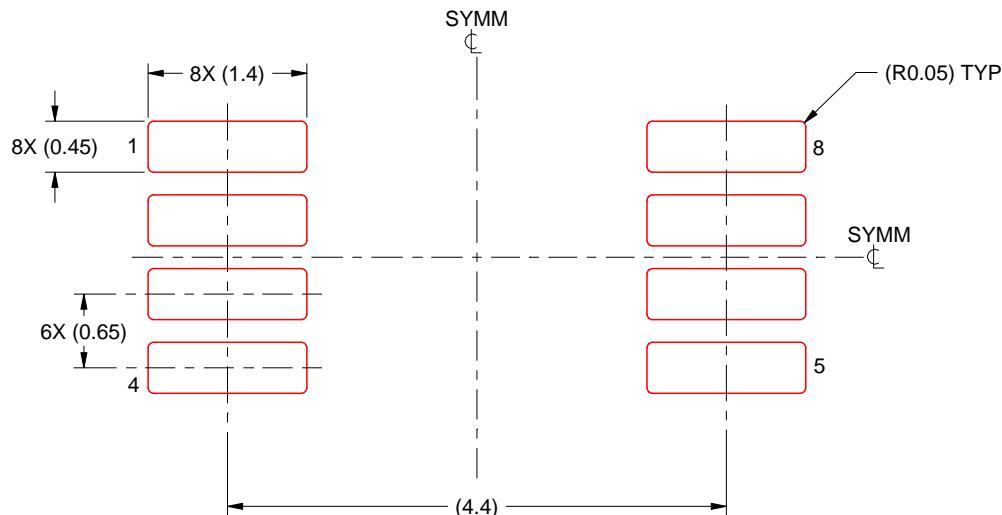
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.
9. Size of metal pad may vary due to creepage requirement.

# EXAMPLE STENCIL DESIGN

DGK0008A

TM VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
SCALE: 15X

4214862/A 04/2023

NOTES: (continued)

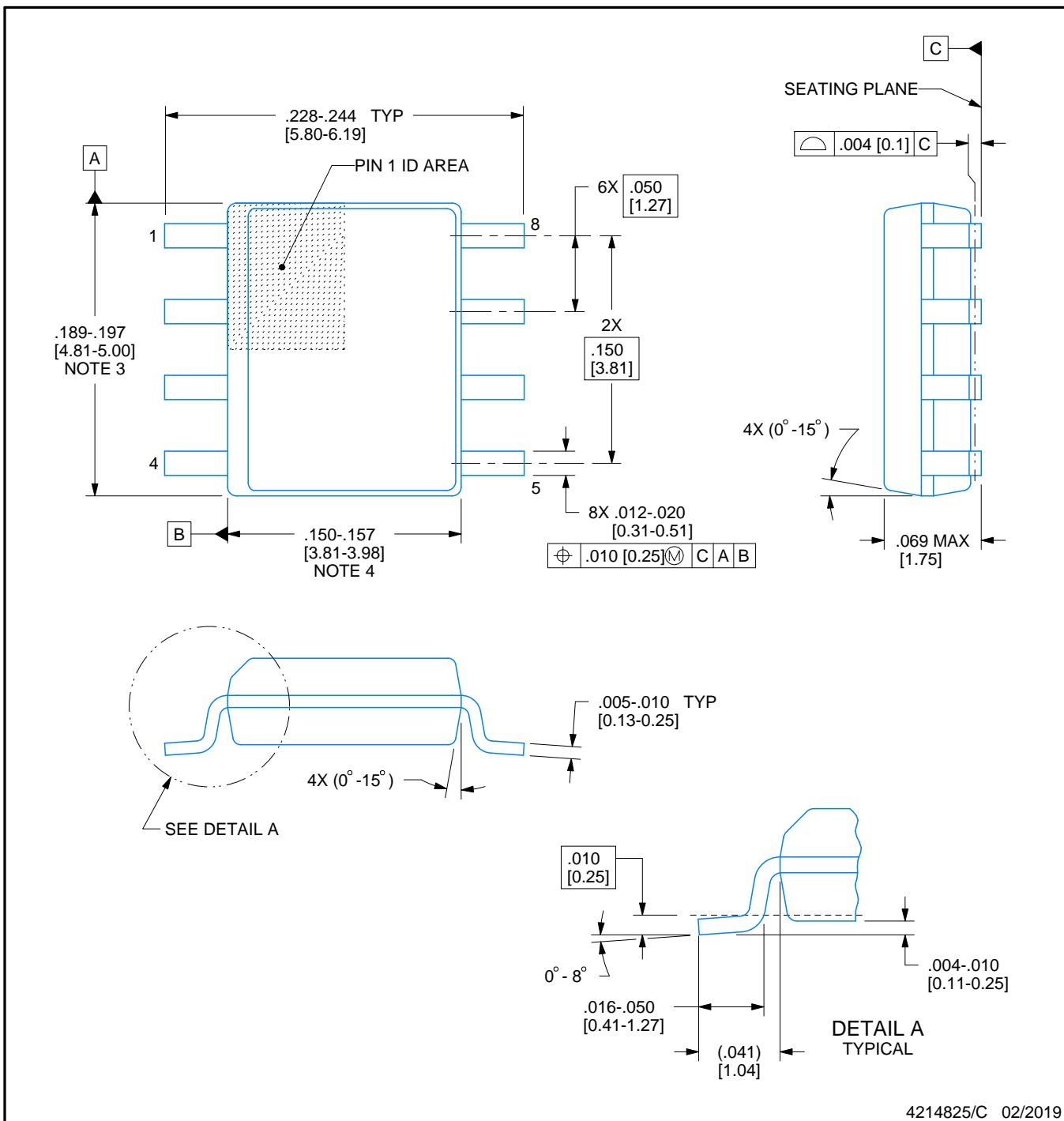
11. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
12. Board assembly site may have different recommendations for stencil design.



# PACKAGE OUTLINE

## SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



### NOTES:

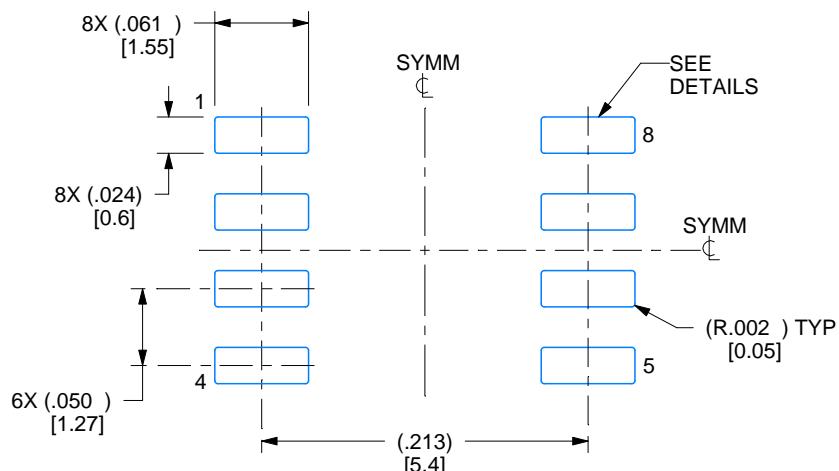
1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.

# EXAMPLE BOARD LAYOUT

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE  
BASED ON .005 INCH [0.125 MM] THICK STENCIL  
SCALE:8X

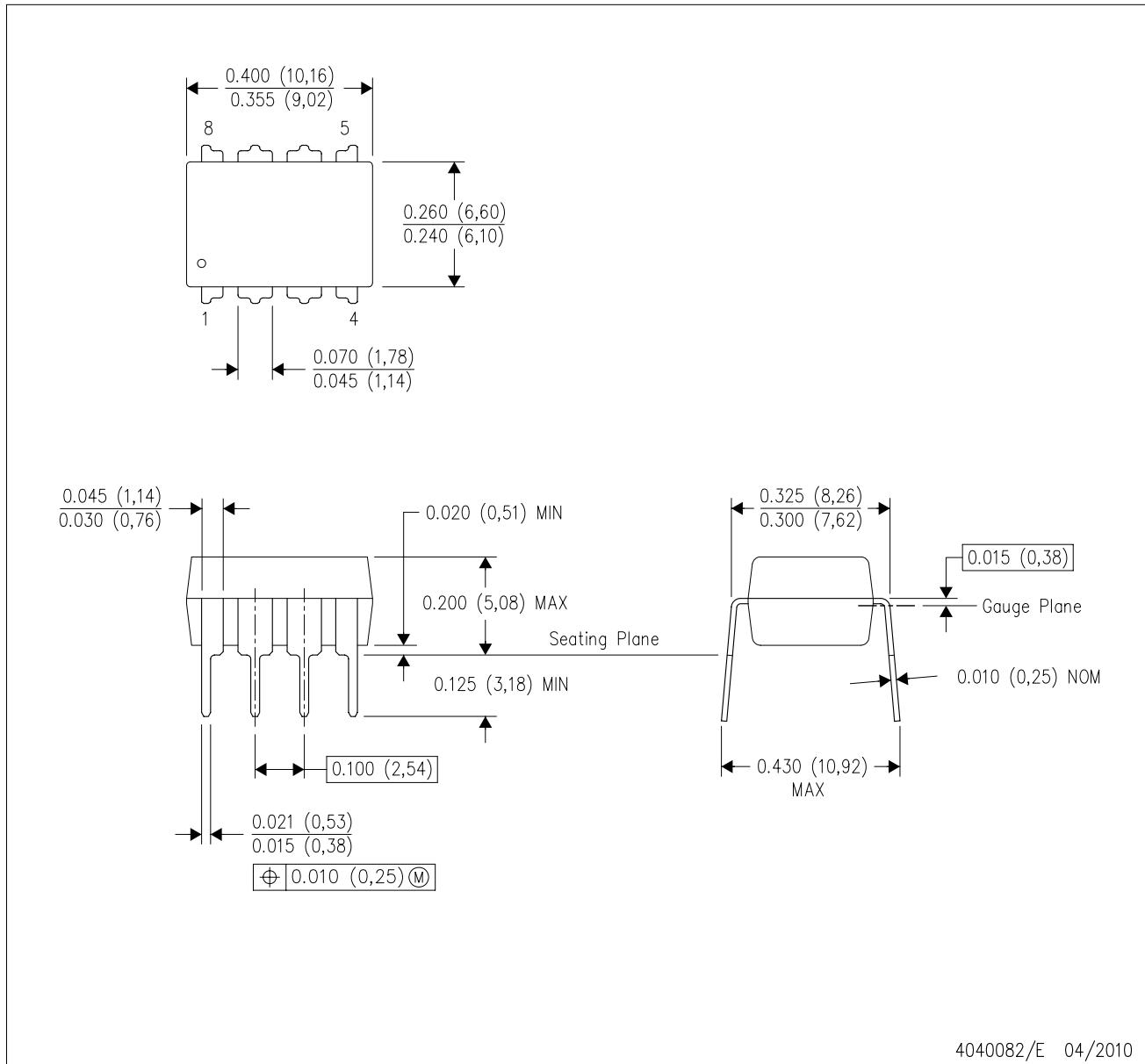
4214825/C 02/2019

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE PACKAGE



NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Falls within JEDEC MS-001 variation BA.

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